# Story of Great Fountain Geyser to 1965

by George D. Marler

Great Fountain Geyser is located on the southeastern corner of the Lower Geyser Basin. It is at the mouth of and on the northern edge of where the small ravine of White Creek enters the basin. White Creek is bounded by numerous moraines and its channel is incised in glacial gravels, indicating that Great Fountain's mound is superimposed on glacial deposits of great, but unknown thickness.

## Early References

Great Fountain has the distinction of being the first geyser in Yellowstone National Park of which there is a written description. In 1869 the Folsom-Cook Expedition, as it came to be known, explored the headwaters of the Yellowstone River to satisfy themselves regarding the truthfulness of numerous trapper and prospector stories of the marvels associated with the region; in the words of Mr. Folsom, "tales of wonderful waterfalls a thousand feet in height, of innumerable hot springs of surprising magnitude and of vast tracts of country covered with the scoria of volcanoes --some of which were reported to be in active operation."

Following its exploration of the upper Yellowstone, and having seen numerous hot-spring groups enroute, this party after leaving Yellowstone Lake crossed the continental divide in order to get back on the drainage of the Madison, and thence to their homes. In doing this they arrived at Shoshone Lake south of the mouth of DeLacy Creek. From here they followed up DeLacy and took a "northwest course", thereby missing the Upper Geyser Basin. They entered the Lower Basin "along a ridge" bordering White Creek. The entry was made at the time of an eruption of Great Fountain. Mr. Folsom's description of the eruption later appeared in the Chicago Western Monthly for July 1870:

> As we decended into the valley we found that the springs had the same general characteristics as those I have already described, although some of them were much larger and discharged a vast amount of water. One of them, at a little distance, attracted our attention by the immense amount of steam it threw off, and upon approaching it we found it to be an intermittent geyser in active operation. The hole through which the water was discharged was ten feet in diameter, and was situated in the center of a large circular shallow basin, into which the water fell. There

> was a stiff breeze blowing at the time, and by going to the windward side and carefully picking our way over convenient stones, we were enabled to reach the edge of the hole. At that moment the escaping steam was causing the water to boil up in a fountain five or six feet high. It stopped in an instant, and commenced settling down--twenty, thirty, forty feet--until we concluded the bottom had fallen out, but the next instant, without any warning, it came rushing up and shot into the air at least 80 feet. It continued to spout at intervals of a few minutes for some time, but finally subsided and was quiet for the remainder of the time we stayed in the vicinity.*

The delight of the party in reaching the geyser basin and seeing Great Fountain is aptly expressed by Charles W. Cook: "We could not contain our enthusiasm; with one accord we all took off our hats and yelled with all our might. We camped just above this geyser on a little stream."

The next reference to Great Fountain was in 1871, at the time of the first scientific exploration of the geyser basins.

> At the mouth of the ravine we found the principal geyser in the group. Its basin was circular and about 60 feet in diameter, although the spring itself, which is in the center, is only about 15 or 20 feet in diameter. The encrusted margin is full of sinuses, filled with hot water, which falls into them whenever the geyser is in operation. These pockets contain, also, smooth rounded pebbles of geyserite varying in size from that of a pea to a large sized walnut. They have been rounded by the water. The water in the spring of the geyser was of a deep blue color and constantly in agitation, though more violently so just before spouting. The column of water projected reaches a height of 100 feet, and is accompanied by immense clouds of steam.+

In naming of the hot springs a precedent was set by the Washburn Expedition. The names given were not of members of the party, but were descriptive of some salient characteristic, such as structure, function, or resemblance to other objects in nature. Many of the names given, particularly of geysers, are adjectives. The first name given to Great Fountain was by Dr. F. V. Hayden in 1871. He named it Architectural Fountain. This name was inspired by both the structure of the mound and the nature of the eruptions. The following year Dr. Hayden renamed it Great Fountain, stating that he though this "a more preferable name and one that will probably be retained."

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*Historical Society of Montana, Volume 5, pp. 367-368.

+U. S. Geological & Geographical Survey of the Territories, Part 2, p. 184.

The structure of Great Fountain resembles a large circular table, the crater being located in the center. The circular platform is 150 feet in diameter and rises 10 to 48 inches above its surroundings. The greatest height is to the north, which is in the direction of the slope of the terrain on which the geyser has built its mound.

While the surface is relatively flat, it is made up of a diversity of sinter deposits, many of which are very delicate and beautiful. Some of the deposits are fantastic in shape and configuration. Artemisia in the Upper Basin, more so than any other geyser in the Park, best compares with Great Fountain in the nature, beauty and weirdness of its deposits. Near the crater are several basins which are always full of crystal-clear water. These basins are of exquisite design, with delicately scalloped rims. Some are large enough that the water stays hot from one eruption to the next. The crater is 13.5 x 19.5 feet and has been plumbed to a depth of 42 feet.

One of the best descriptions of Great Fountain's structure was made in 1872 by Mr. W. H. Holmes. Mr. Holmes was a member of the Hayden Survey and "artist to the survey."

> In approaching the crater of this geyser the observer is not at first impressed with the importance of this geyser, as the outer rim of the basin or rather table--in the canter of which the fissure is situated--is raised but two or three feet above the general level. This elevated part I should estimate to be upward of 120 feet in diameter, and, with the exception of the crater, is built up nearly to a level with the border. The surface, formed entirely of siliceous deposit, is diversified by an infinite number of forms and colors. The depreseed part in some places is so level and white and hard that a name could be engraved as easily and as well as upon the bark of a beach-tree. In others there are most exquisitely modeled basins and pockets, with ornamented rims, and filled with perfectly transparent water, through which thousands of white pebbles of geyserite could be seen lying in the white, velvety bottoms. Rising above the general level are innumerable little masses and nodes of cauliflower-like and beaded silica, standing out of the water like so many islands. Those near the center swell into very large rounded masses. The whole surface is so solid that I walked, by stepping from one elevation to another, up to the very brink of the fissure, where I looked down with no little apprehension into the seething cauldron, where 12 to 15 feet below was a mass of dark green water in a constant state of agitation, threatening an eruption. The crater is about 10 feet in diameter, lined with irregular coating of beaded silica.*

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* Geological Survey of the Territories, Vol. 2, Hayden, pp. 143-144.

An interesting description was written in 1895 by Hiram Chittenden.

> The Great Fountain lies a mile and a half south-east of the Fountain. It is the chief wonder of the Lower Basin, and, in some respects, the most remarkable geyser in the Park. Its formation is quite unlike that of any ohher. At first sight the visitor is tempted to believe that some one has here placed a vast pedestal upon which to erect a monument. It is a broad, circular table about two feet high, composed entirely of hard siliceous deposit. In its surface are numerous pools molded and ornamented in a manner quite unapproached, at least on so large a scale, in any other part of the Park. In the center of the pedestal, where the monument ought to stand, is a large circular pool of great depth, full of hot water, forming to all appearences, a lovely quiescent hot spring.*

## Early Difficulty of Reaching Great Fountain

For both ingress and egress to the geyser basins of the Firehole, early routes of travel left Great Fountain completely isolated. It was only by taking a side trip over a roadless and near trailless terrain that observation of this geyser was possible. That this situation existed as late as 1890 is evfdenced by a guide book published that year. In reference to Great Fountain, A. B. Guptil wrote: "Here are situated numerous geysers, among them the Great Fountain, a very powerful one, which will add greatly to the Park attractions when made accessible. The only possible way of reaching Great Fountain at present, with anything like safety, is by saddle animal, following up the bed of Fountain Creek." [Tangled Creek].

In the late 1890's a side road was built to Great Fountain, which later was made into a loop, rendering easy access. However, this important geyser is still off the main route of travel.

## Early Descriptions of Eruptions

In a guide book published in 1909 Reau Campbell notes that Great Fountain is infrequently observed by Park visitors. "It is two miles from the Fountain Hotel, one mile down the circut road; rarely seen by the average traveler." Despite its unfavorable location for early observation, data on Great Fountain's functional behavior is as complete as for most of the geysers in the Upper Basin. However, in all cases there is a surprising paucity

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* Yellowstone National Park, Chittenden, p. 224

of information which apparently resulted from disinterested officials (particularly true during the period the Park was administered by the Army), and a lack of systematic observation.

Since Great Fountain was first described by the Hayden Survey it has been a focal point of observation by a number of scientific expeditions and other parties interested in publishing guide-book information on important hot-spring units. However, most of the investigations, particularly those of a scientific nature, occurred during the early period following discovery.

The early interest in Great Fountain was due not only to the unusual character of the mound, but also the spectacular nature of the eruptions which recurred with a fair degree of regularity. In 1872 W. H. Holmes left not only a pleasing and accurate description of the mound, he also recorded his impression of an eruption. At the time of his inspection of the crater, as noted above, he states:

> The water soon began to rise, plunging from side to side in great surges, sending up masses of steam and emitting angry, rumbling sounds. The demonstration caused a precipitate retreat on my part, to the border of the basin, thinking that I could appreciate the beauties of a scalding shower-bath better from that point.
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> An irregular mass of water was thrown into the air in utmost confusion, spreading out at every angle and whirling in every direction, some jets rising vertically to a height of 60 to 80 feet, then separating into large glistening drops and falling back into the swirling mass of water and steam; others shooting out at an angle of 45 degrees and falling upon the islands and pools 30 to 40 feet from the base. The eruptive force, for a moment, dies away and the water sinks back into the tube. Then with another tremendous effort, a second body of water is driven into the air; but with a motion so much more simple than before that the whole mass assumes a more regular form and is like a great fountain with a thousand jets, describing curves almost equal on all sides and forming a symmetrical whole more varied and grand than any similar work by man. The intermittent action continues for nearly an hour, but is so constantly changing that at no two moments during the time are the forms and movements the same. The eruptions are repeated at irregular intervals of a few hours and are not known to vary essentially from the manner of action here discribed; yet I have good reason to believe that at certain times there is a much greater exhibition of power.*

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* Geological Survey of the Territories, Hayden, 1872, pp. 143-144.

A guide book written in 1901 in describing Great Fountain's uptions states:

> The outburst comes violently and lifts an enormous mass of water from the whole pool, some 15 feet in diameter. The eruptions follow each other quickly at first. It then takes matters more leisurely, and, alternately, boils furiously and throws out its seething contents, for an hour and a half. The first three explosions are usually the finest. Some of them are very violent, and the mixture of water and steam and the variety of effects produced are beautiful beyond description.*

Early descriptions of Great Fountain's eruptions when compared with later and present day ones, are indicative that since its discovery by the Folsom-Cook Expedition there has been a remarkably stable pattern of eruptive behavior. At times there are wide variations in the power of its displays, but apart from that an accurate description of an eruption in 1870 would in big measure be applicable today.

## Regularity

Regularity as applied to geysers is a relative term. None is regular if the term is used to denote set periods. Many, like Great Fountain, approach regularity to a sufficient degree to make predictions of the approximate times of their eruptions possible. In addition to a rhythm in frequency, Great Fountain possesses another invaluable quality which makes it possible for the experienced observer to predict the probable time of an eruption without knowing the time of the previous one. From the time of one eruption to the next there are progressive changes in and about the crater which are indicative of the approximate time elapsed since the last eruption, which in turn, due to periodicity, enable the observer to estimate the probable time of the next eruption. In cases where the ensuing eruption is much over or under average in length of interval a much bigger percentage of error is involved. However, without a knowledge of the time of the last eruption, preeruption symptoms which precede an active phase by 1 to 3 hours are invaluable in predicting the time of eruptive activity.

The earliest reference to the frequency of Great Fountain's activity is found in W. C. Riley's guide book published in 1890. He states: "The action of this geyser continues an hour; and occurs every twelve to twenty hours." Hayne's Guide, 1896, states

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* <u>Yellowstone National Park</u>, 1901, Wheeler, pp. 68-69.

that "Eruptions of Great Fountain occur every 10 to 12 hours." In 1901 in his guide to the Park O. D. Wheeler states, "It appears to play with moderate regularity every eight to eleven hours."

Following the creation of the National Park Service reports on geyser activity which had been almost wholly lacking for a 20 year period began to find their way into Park superintendents' monthly and annual reports. During the 1920's Superintendent Horace M. Albright's reports reveal that Great Fountain was erupting about "every nine to twelve hours." In his 1927 Annual Report Mr. Albright states: "All observed eruptions of Great Fountain have been normal in point of time, power and volume. It is the second largest fountain geyser in the Park and in many respects the most attractive." Superintendent Albright was intensely interested in the hot springs and kept in close touch with them.

That there were periods during the 1920's when occasional intervals of Great Fountain were much over the "nine to twelve hours" range is indicated by a report of Ranger Charles Phillips, one of the Park's most devoted geyser students. In the 1927 Ranger Naturalist Manual Ranger Phillips states: "Its interval is somewhat irregular but it may be depended upon to play at least once in twenty-four hours."

Since the 1930's Great Fountain's summer behavior has been under fairly close surveillance. Reports by the author commencing in 1938 and, except for the World War II period, continued to date, reveal that prior to the 1959 Hebgen Lake Earthquake Great Fountain's intervals ranged between about 9 and 19 hours, with 12 hours a near average for most seasons. From 1939 to 1959 the seasonal average varied between about 11 and 13 hours. The pre-earthquake frequency is indicated by reference to one or two of the author's reports. 1949-- "During the entire season Great Fountain has played with a greater degree of regularity than during any previous season it has been under my obbservation. The eruptions occurred approximately every twelve hours. From five to seven days at a stretch it has been playing at about the same time each day. Then one or two long periods would intervene, advancing the time from four to six hours, following which the eruptions would occur again at about the same time each day for the length of period indicated." 1956-- "During the season 75 eruption intervals were determined for Great Fountain. The great majority of the eruptions came within one hour of the seasonal average which was 11.5 hours." 1958-- "Between April 1 and September 10 the number of eruption intervals determined for Great Fountain was one hundred seventy-four. The length of the intervals varied between nine hours and fifteen minutes and fifteen hours and six minutes; these being the extremes. The average time was twelve hours and twenty-four minutes."

## Earthquake Shortens Interval

In 1959 up to the time of the earthquake, which occurred on August 17, Great Fountain's eruptive behavior was comparable to that of 1958. The average was 12 hours and 46 minutes; the extremes 9 hours and 42 minutes and 17 hours and 10 minutes. Following the earthquake it was soon evident that Great Fountain's eruptive pattern had undergone marked alteration.

> The first determined interval was on August 22. It was 3 hours and 40 minutes! Nothing even closely comparable to this had ever been checked before. During succeeding days all the eruption intervals showed that Great Fountain was playing with unprecedented frequency. During the first two weeks 6 hours and 41 minutes was the longest interval noted.
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> From September 18 to 20 inclusive, by means of Germeraad's eruption recorder, eleven successive intervals were checked. The shortest interval was 3 hours and 10 minutes, the longest 9 hours and 3 minutes, the average time being 5 hours and 46 minutes.
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> During succeeding weeks occasional checks were made that were indicative there was a progressive, but slow, increase in eruption time. By December, from limited data, the average time was 7 1/2 hours. The longest interval checked was on November 30, and was 9 hours and 15 minutes. This was but 12 minutes longer than an automatically recorded eruption on September 18.*

From December 1959 through 1964 the average time stayed under 8 hours. During this period the minimum interval checked was 4 hours and 55 minutes, the longest 10 hours and 18 minutes; the average time being 7 hours and 48 minutes. Since the 1959 earthquake Great Fountain has been erupting almost twice as frequently as during the seasons immediately preceding the earthquake.

## Great Irregularity

The above data are indicative that Great Fountain's eruptive pattern over the years has been of a nature which permits it to be classed as one of the Park's regular geysers. Yet, on occasions, which only recently were noted, it exhibits unusual behavior, resulting in great irregularity. This great irregularity was first noted in 1957. Until November and December of that year no late-

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* Geology File, Yellowstone Park Reference Library, Marler, pp. 37-38.

season observations of geysers in the Lower Basin had ever been attempted. Systematic winter observations are still lacking. Of the 1957 late-season observations the author has written:

> The first indication I had that Great Fountain was showing a different behavior pattern than has ever been observed in summer was on November 19. At the time of this observation it was in a state of overflow, which overflow had always been known to precede the eruption anywhere from an hour to an hour and a half. The condition of the overflow indicated that the eruption could be expected in about the next ten minutes. Never having photographed this geyser in winter surroundings (the day was clear) I selected a favorable position and awaited an eruption. After waiting over half an hour and becoming more impatient and perplexed because of no eruptive activity, I approached the crater. To my surprise, no change in the degree of boiling had taken place during the period of waiting. After further vigil there was still no change. Three hours later I returned to find the same state of overflow and that the boiling was no more vigorous than when first observed.
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> Before leaving the scene I placed markers to determine if an eruption might take place during my absence. When visited on the 20th, both morning and afternoon, no eruption had occurred. It was still in what looked like the late stages of overflow preceding an eruption, which normally occurred about every 12 hours. Sometime during the night of the 20th it erupted. Twice during November and once in December this same overflow condition was known to have occurred, lasting for periods comparable in length to the first observation. This same condition was observed twice during November 1958. Due to the closing of the road I was unable to observe Great Fountain during December 1958.*

These long periods of overflow of Great Fountain resulted in intervals of somewhere between 36 and 48 hours. Such great variations from average time were without precedent. It had become axomatic that overflow was a brief precursor to an eruption. The first conclusion drawn following the strange overflow behavior was that, in spite of all previous observation to the effect that geysers are not affected by atmospheric temperature, here was one which showed response to the cold of winter. Long observation, however, had firmly established the fact that most geysers are eccentric. After long periods of more or less set patterns of play, the nature of their activity can vary considerably, due to an underground shift of the thermal energy to another spring or geyser, with a later shift back to the former pattern. These variations are not

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* Seasonal Changes in Ground Water in Relation to Hot Spring Activity, American Journal of Science, Vol. 262, May 1964, pp. 677-678, Marler.

dependent upon the season of the year. In the case of Great Fountain there was certainly the possibility that these long periods of overflow merely represented a shift to some previously unobserved condition, wholly unrelated to atmospheric temperature.

### Low Ebb as a Cause of Great Irregularity

On November 8, 1962 it was discovered that great irregularity of Great Fountain can also result from a condition which would appear to be wholly unrelated to long periods of overflow. On the above date when a routine check was being made it was noted that the flow of water of an earlier eruption from the large circular terraces surrounding the crater had completely ceased. Many years of observation had shown that when this situation exists sufficient time has elapsed since the previous eruption for this geyser again to be near a state of overflow. The overflow is a precursor to an eruption. Not only was there no evidence of immediate overflow, but when the crater was approached it was discovered that the water stood 8 to 9 feet below the rim of the crater, with the water realtively calm except for occasional sizzling where surface tension was broken near the walls. It had been observed that always following an eruption of Great Fountain there was near constant surging and ebullition in the crater as it gradually refilled, with water never being more than 3 or 4 feet below the rim of the crater.

During a 3 hour period following the discovery of low water in the crater no changes were in evidence, either in rise in temperature or water level. Sometime during the following night an eruption occurred. No further late season observation was possible due to abnormally early closing of the road.

Low ebb such as described above was not again observed at Great Fountain until the morning of October 27, 1964. At the time of this observation the water level was down about 9 feet below the rim of the crater. Like the 1962 observation there was no boiling except where the water touched the sides of the bowl, resulting in slight sizzling, indicating a superheated state. The state of the water on the terraces indicated it had not been less than 20 hours since there had been an eruption. The water remained at low ebb thgough all of the 27th and 28th. Sometime during the night of the 28th it erupted. The interval was in excess of 48 hours.

### Cause of Great Irregularity

To date no observation has presented evidence suggestive that Great Fountain has subterraneous connections with any other thermal spring. If connections exist they apparently are quite indirect. This seemed to rule out a shift of the thermal energy as a possible cause of strange late-season behavior. Observations made during this period

in the Fountain Group suggested an explanation for the cause of Great Fountain's unusual states which is quite apart from possible effects of external temperature, or a shift of the thermal energy; an explanation which might be more fully in accord with the facts.

During the 35 day period in November-December 1957 that the geysers in the Fountain Group were under observation the activity of the major geysers was well below that of the previous summer. Marginal observations made during the 1950's (late fall and early spring) presented certain evidence that none of the major geysers in the Fountain Group is as active in winter as in summer. When observed in the spring it was always noted that the sinter surrounding the craters of Morning, Fountain and Clepsydra showed no evidence of recent activity. Further, the growth of the algae in the margins of the craters of Morning and Fountain (Clepsydra is a cone-type geyser) indicated a period of dormancy.

The decline of activity in this group in winter posed a rather complex problem. That this decline might result from surface cooling is highly improbable. This assumption is based on the observation that geysers with large open craters, such as Morning and Fountain, are not affected in eruptive activity by low atmospheric temperatures. The geysers to which reference is made are located in the Upper Basin and include Grand, Oblong, Giantess, Artimesia, Sapphire, etc.

## What the Fountain Paint Pot Springs Reveal

The Fountain Paint Pot is a part of the Fountain Group. Observations made here in late 1957 seemed to offer a satisfactory explanation, not only for the unusual behavior of Great Fountain, but for declining activity in winter of big geysers in the Lower Basin. Whereas the Paint Pot is very different in character from nearby springs in the Fountain Group, its close proximity makes it highly probable that it and all springs in this group are connected, in varying degrees, to the same water source. Further, if connections exist, any variation in supply and temperature of ground water might be reflected in all springs in the group.

When the Fountain Paint Pot was observed in Mid-November 1957, I was greatly surprised to note that the mortar-like mixture was more fluid than it had been in September; also that the general level of this large mud cauldron had risen over a foot. The nature of the activity made it highly suggestive that the temperature had declined from its September reading, 95$^{\circ}$C. Readings taken on December 3 and 13 showed the temperature to be 90$^{\circ}$. The temperature had also dropped in both Fountain and Morning. In September the temperature of Fountain was 72$^{\circ}$, Morning 90$^{\circ}$. By December these temperatures had dropped to 67.5$^{\circ}$ and 87.5$^{\circ}$ respectively. The boiling temperature is 93$^{\circ}$C.

Heavy storm will noticeably increase the fluidity of mud springs due to their inherent and necessarily scanty water supply. In trying to interpret the cause of the conditions existing in the paint pot this factor was given due consideration. However, there had been no recent storms of any consequence in the area. Further, it was a period of drought in the Park. The possibility that the increased water supply and lower temperature might be seasonal presented itself. Comparative data for these speculations were completely lacking. However, during the succeeding seven years the state of the Fountain Paint Pot has been closely observed. These observations clearly indicate that the late autumn change described for these mud springs is indeed seasonal in its recurrence.

The most plausible explanation for this condition is that meteroic water available to these springs is augumented in early autumn, rather than immediately following the melting of winter snow. Certain effects of the 1959 earthquake support this hypothesis. The quake not only greatly stimulated and increased the areal range of activity of the Paint Pot and caused a rise in water level, but new mud springs began developing outside the main crater to the north. By mid-September 1959 one of the new springs, under considerable steam pressure, was ejecting reddish colored muddy water. It was given the name Red Spouter.

During all of the 1959-60 winter the Red Spouter, without any known cessation, ejected its tinted liquid. By the end of May 1960, when the melting of snow on the surrounding plateau was at a maximum, the liquid part of the eruption ceased, resulting in the Spouter becoming a hissing steam vent. At this same time the Paint Pot began its seasonal drop in level. In late September, Red Spouter again changed its state to that of a steady geyser, and synchronously with this transition, the mud began rising and thinning in the Paint Pot. During all succeeding seasons the above-described changes have taken place at about the same time of the year with not more than a month's variation. The water level in nearby Leather Pool also shows a sympathetic response to changes in level of the mud springs. These conditions would seem to present incontrovertible evidence that ground water is higher in this area in winter than in summer.

The rise of ground water in the Paint Pot springs in autumn rather than at the time of melting snows, offers a reasonable explanation, wholly unrelated to atmospheric temperature or exchange of function, as to why some geysers in the Lower Basin erupt less frequently in winter than in summer. I also affords an explanation for Great Fountain's occasional digression from its summer eruptive pattern. The late season changes in some of the Lower Basin springs apparently result from the temperature and rate of movement of the ground water. Topographic and geomorphic conditions in the Lower Basin would

appear to be such that the bulk of the great addition of ground water during the early part of the year does not become available to many groups of springs in this basin until several months after its seepage into the ground. It is not coincidental that eruptive activity of Morning, Fountain and Clepsydra becomes much less frequent at the time new water addition shows in the Paint Pot springs; also that Great Fountain's pre- and post-eruption behavior shows occasional alterations at this same time. They are subject to a cooler body of ground water.*

As a result of the 1959 earthquake Morning and Fountain Geysers became dormant; Clepsydra changed to a steady geyser. In 1963 Fountain rejuvenated but on a changed pattern of activity. Due to these changes these geysers no longer follow the summer-winter pattern they did previous to the earthquake. These changes came about as a result of the shifting of the major foci of the thermal energy to other subterraneously connected springs.

## Cause of Long Overflow and Low Ebb

Long periods of overflow and low ebb in Great Fountain would appear to be antithetical conditions. It is believed, however, that both result from the same general cause--a cooler body of ground water which is so beautifully illustrated by the Paint Pot and Fountain group of springs. That Great Fountain's abnormal behavior should occur at the seme season of the year as additional and cooler water appears in the Fountain area would scarcely seem to be coincidental.

The long periods of overflow indicate a reather delicate balance between available magmatic steam and eruptive behavior. The influx of cooler water retards the heating of the water to the critical temperature of an eruption. Why this occurs for some late-season eruptions and not others is unknown. It would suggest that the flow of heat or water, or both, is not constant.

The low ebb and other unusual conditions which were observed in Great Fountain in 1962 and 1964, like the long periods of overflow, are apparently the result of a cooler body of ground water. In the case of the slow response of Great Fountain in overcoming the effects of the low ebb an additional factor other than cooler water was involved, namely an unusually heavy influx of ground water at the end of the eruption. That the replacing of discharged water during and following an eruption is not always steady is amply demonstrated by the behavior patterns of many geysers. It is the inflow of water, cooler than that of an eruption, that terminates a geyser's activity. Many geysers, Old Faithful in particular,

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* Seasonal Changes in Ground Water in Relation to Hot Spring Activity, American Journal of Science, Vol. 262, May 1964, pp. 681-682, Marler.

show that this inflow will at times come suddenly abruptly stopping the eruption. It is believed that it was the heavy influx of cooler water that resulted in the abnormally low ebb and slow response of Great Fountain in overcoming the effects of the eruption.

The low ebb of Great Fountain in 1962 and 1964, with its resulting delay in eruptive activity, was a marked innovation in behavior f from anything I previously had observed. There is no other reference in the literature to this situation. This does not imply that it is new and unusual in occurrence. As earlier stated, no winter observations of Great Fountain have ever been attempted. It is only in the past seven years that any late -autumn observations have been made. However, that the water in the crater might ebb far below what is considered as normal, and behave in an unorthodox manner, is indicated by two of the earliest references. When describing the eruption witnessed on October 1, 1869, Mr. Folsom stated: "It stopped in an instant, and commenced settling down--twenty, thirty, forty feet--until we condluded the bottom had fallen out, but the next instant, without any warning, it came rushing up and shot into the air at least 80 feet." At the time of an eruption witnessed by W. H. Holmes in 1872 he stated that he walked "to the very brink of the fissure, where I looked down with no little apprehension into the seething cauldron, where 12 or 15 feet* below was a mass of dark green water in a constant state of agitation, threating an eruption." While making this observation of the crater the water began to rise in surges, which was followed by an eruption.

Both Mr. Folsom and Mr. Holmes were careful and critical observers. Their descriptions of the natural phenomena they observed in the Yellowstone country are devoid of ambiguities and exaggerations. That no one since these dates has described a similar situation of low water, and what seems peculiar behavior of Great Fountain, does not detract from the validity of the early observations. Most major geysers in their functional behavior have shown a wide range of versatility. This is one of their important attributes that holds a particular fascination to the interested observer.

## Pre-Eruption Symptoms

There are few geysers in Yellowstone Park where pre-eruption symptoms are as definitive as they are at Great Fountain. It is one of but few big geysers which overflows prior to an eruption. The earliest reference to overflow as a sign of impending activity is found in Hayne's Guide by Guptil in 1896. "The indications of an eruption are quite reliable, thirty minutes from the time the

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* The italics are the author's.

crater basins are filled with water, and the same begins to overflow, the eruption takes place." It is here recognized that overflow of the crater preceded an eruption. However, the timing of overflow apparently did not begin until the basins about the crater were filled and began to overflow. In 1901 O. D. Wheeler wrote: "Before eruption, and just previous thereto, it gradually fills both basins, and when the drainage begins to seek the various outlets, the display may be looked for."

The above references are indicative that the nature and time of the overflow were not too well known during this early period. This is not surprising when Great Fountain's isolated position and infrequent visitation are taken into consideration. Forty years after discovery it was still "rarely seen by the average traveler." By 1901 some of the characteristics of the overflow and its importance in predicting an eruption were pretty well established. In Campbell's Guide for 1909 it is stated: "The Great Fountain will play when its crater is full and overflowing and the water is running down over the formation. There is a little pool about two by three feet within ten feet of the crater; when this begins to fill there is an hour in which to communicate with the hotel, if anyone is on watch, and the guests will have time, if they hurry, to see one of the finest displays in the Park."

Following Campbell's observation there is no further reference to overflow until 1932. Careful observation that season by an interested park visitor known as "Geyser Bill", who spent several seasons in the geyser basins, revealed that overflow preceded an eruption by about 1 hour and 15 minutes. Further, these observations, apparently for the first time, showed that overflow usually starts, only to ebb, one or more times before the final overflow preceding an eruption. In 1938 the author reported that "The overflow precedes the eruption by about 1 hour and fifteen minutes. The overflow never seems to be less than one hour and seldom more than one hour and a half." This condition persisted until the time of the 1959 earthquake.

## Progressive Changes from Eruption to Eruption

In discussing the degree of regularity manifested by Great Fountain it was stated that pre-eruption symptoms are such as to make it possible for the experienced observer to predict the probable time of an eruption without knowing the time of the previous one; that from one eruption to the next progressive changes in and about the crater are indicative of the probable time elapsed since the last eruption. Some of these changes are now considered.

The large circular table or pedestal forming the top of Great Fountain's mound, with its numerous shallow collecting basins, separated by small masses and cauliflower-like domes of sinter,

hold a considerable amount of water. The outer border of the pedestal for the most part is fringed by upturned deposits. Thus a large collecting basin is formed from which, through a few gaps in the sinter fringe, water slowly drains following an eruption. The volume of this flow slowly decreases. To one familiar with the rate of flow in all its stages a reasonable guess can be made as to the time elapsed since an eruption. In about 8 hours all drainage ceases. When the average intervals were 11 to 12 hours, as before the 1959 earthquake, by the time of cessation of drainage the degree of rise of water in the crater was a further indication of the time when overflow might start.

During Great Fountain's quiet phase there is a rhythmic ebb and flow of water in the crater. The rate of rise of the water is quite rapid, reaching a maximum in about one minute. After about half a minute the ebb starts and is completed in less than a minute, the water dropping 8 to 12 inches. From 40 to 45 minutes elapse between each surge or flow period. With each succeeding surge, for most eruptions, the rise of water in the crater is in excess of the previous surge. This finally culminates in overflow from the crater into a large basin on the northside of the crater and a smaller one on the west, and occasionally over a depression to the east. For the most part during the 1940's when the flow started, particularly over the east border, there was no further ebb; the overflow continued until the time of the eruption, about 75 minutes later. However, during the 1950's until the time of the earthquake, following the initial start of overflow there would be two and sometimes three periods when overflow would commence, only to ebb for 40 or more minutes before the final overflow preceding the eruption.

During the pre-eruption overflow at about 5 minute intervals, there are short periods of increased boiling. Each succeeding ebullition is more vigorous than the preceding one. About 15 minutes before the eruption the boiling will be accompanied by surging. Each surge is more vigorous until one of them is sufficient in degree to initiate the eruption.

## An Eruption

Early descriptions of eruptions already cited are pertinent today. The discussion here will deal mainly with mechanics.

When an eruption commences the water which momentarily has been surging up about 3 or 4 feet will suddenly increase in vigor, rising up about 8 or 10 feet. Then, as if weary, the water drops to be followed immediately by a surge more violent than the previous one. After one or more preliminary plays of this character an explosion arches the doming water into a lovely fountain. Explosion

follows explosion, some more powerful than others. The most voluminous part of the discharge occurs during the first few minutes. The bigger explosions will send a wall of water rolling across the pedestal in all directions.

The above, in general, is the manner in which an eruption of Great Fountain is initiated, however, no two eruptions are essentially alike. Theeruptions follow a pattern, but there are occasional wide variations in this pattern. At times the highest burst comes with the first explosion, but usually two or more explosions occur before maximum height is reached. On infrequent occasions the initial big burst will come with a minimum of preliminary doming. When this occurs a beautiful spectacle is afforded. The entire body of water in the big crater is suddenly lifted high in the air. For an instance the great mass of water is so compact and dense that the geyser is more blue than white.

An eruption of Great Fountain is usually divided into four separate periods. The active phases last from about 5 to 7 minutes, during which bursts occur every 10 to 20 seconds. Following each active phase all surging and bursts cease for periods ranging from 5 to 9 minutes, the longer interludes being near the end of the eruption. During each active phase the bursts as a rule become more enervated. However, on infrequent occasions I have seen the highest burst occur during the second phase. It usually takes about an hour to complete the series which makes up the eruption.

## Height of an Eruption

The height to which many geysers erupt is quite variable. In answering the query as to how high a geyser plays, almost invariably it is the maximum height that is given. The height generally assigned to Great Fountain over the years is 100 feet. The first reference to height was in 1869, at the time of the first recorded observation. Mr. David E. Folsom stated "it came rushing up and shot into the air at least 80 feet." This party did not see the beginning of the eruption. In reference to an eruption observed in 1871 Dr. Hayden stated, "We saw one eruption in 1871 estimated to be about 100 feet in height."

Most of the separate bursts of an eruption are much under 100 feet in height. Usually only one of the bursts reaches near maximum which for some eruptions is scarcely more than 60 to 80 feet. However, a near 100 foot burst would be accurate for most. During an eruption the great majority of bursts are between about 15 and 50 feet. The really spectacular explosions come during the first few moments of activity. These initial explosions at times vary greatly in force and power, as well as in volume of

water discharged. During the 1950's some of the initial bursts were of unprecedented size and height. In reference to the 1955 activity the author wrote: "Like Morning Geyser, Great Fountain is extremely variable in the nature of its eruptions. During the past season this was particularly true. The highest bursts for some eruptions were not more than 75 feet, while others reached double that height. An eruption observed on August 18 impressed me as being the most spectacular burst of water I have ever witnessed from any geyser in Yellowstone National Park." Its height was estimated to be in excess of 200 feet. This, in connection with the huge mass of rocketing water, made it a never-to-be-forgotten sight.

From about 1954 until the 1959 earthquake, Great Fountain, especially in late summer, was the scene of many eruptions when one or more bursts would be greatly in excess of 100 feet, with some in the 200 foot range. Of its 1956 activity the author reported:

> Each season the Great Fountain's popularity as a major geyser is growing. This is due, not only to increased accuracy in predicting eruptive periods, but as a geyser it is proving that it possesses a potential second to none. During the past few seasons, in the latter part of these seasons, it has been the scene of occasional bursts of water which far surpass in magnitude any of the earlier records. If previous to the past few seasons it had been showing a similar pattern of eruptive activity it is highly improbable these occasional grand displays would have escaped observation, especially in view of the fact that in recent years it has been under fairly close surveillence. The Great Fountain would seem to be, either in a new but recurring cycle of activity, or in a new stage of evolution.*

Since the 1959 earthquake it has been less frequent that Great Fountain has been observed to erupt in excess of 100 feet. However, occasionally there are magnificent bursts which greatly exceed that figure. In 1963 Park Ranger Naturalist William J. Lawis spent considerable time observing the geysers in the Lower Basin. Relative to Great Fountain he wrote: "The strength of the eruptions increased as the summer progressed. It has been my observation over the years that the eruptions are higher in August than in June. On September 1, I witnessed the highest eruption I have seen since the 1959 earthquake--near 200 feet."

No doubt a number of coordinate factors are involved in making possible what might be termed huge eruptions. One seeming necessary condition is the manner in which the eruption is initiated. At the beginning of most eruptions the first minute or two are

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* Geyser Report for Firehole Basins, 1956, Marler

marked by several rapidly recurring bursts of water. This seems to destroy the height potential for the much over verage bursts. It has been my observation that those which are much over average in height occur only as a result of the following condition: Following a surge or two of about 15 to 20 feet, indicating that ther eruption has started, it is most important that all action cease. The longer the pause the mightier the ensuing explosion. This is not infallible. At times, even after a long pause, there will be several rapidly recurring jets much below 100 feet. However, I have never seen a much over average eruption occur except when the above described conditions obtained. Whether the eruption is of a major character seems to depend, in part at least, on the amount of energy dissipated by minor surging before the main burst comes.

## General Effects of the 1959 Earthquake

The story of Great Fountain would not be complete without further reference to the effects of the 1959 earthquake. It was pointed out earlier that the big tremor had a marked effect upon the interval, resulting in the eruptions occuring more than twice as frequently during the first few days following the jarrings. The eruptions still occur almost twice as often as before the earthquake (See topic, Earthquake Shortens Interval).

The marked shortening of the eruption intervals was not the only effect the earthquake had on Great Fountain. Many of its pre-eruption symptoms underwent alteration. It has been Great Fountain's habit during the period I have observed it for the water to drop about 4 feet in the crater following an eruption. The water would then slowly rise, taking from 3 to 4 hours for the crater to fill. Following an eruption there would be violent boiling which would gradually subside as the water rose in the crater. The rise of water resulted in a slow drop in temperature. By the time the crater filled to near overflow the boiling completely subsided over the main portion of the crater. The water would still be superheated, ranging between 200 and 202$^{\circ}$F. This resulted in frequent bubbling on the edges where surface tension was broken by the crater walls.

For several weeks following the earthquake the crater would refill within 60 to 90 minutes following an eruption. Instead of the water being placid at this time it was in a constant state of ebullition. The former ebb and flow periods were wanting. The surface level would fluctuate not more than an inch; and on two occasions the overflow preceding an eruption was observed to start within about 10 minutes following complete filling of the crater. One eruption was preceded by overflow by only 33 minutes. Instead of there being three or more surging periods at about 5 minute intervals before an eruption, the eruption would come with the first surge; instead of lasting for about an hour the active phase was completed in 30 to 45 minutes.

The above condition continued throughout the rest of 1959, and with slow modification during 1960. During 1961 the pre-eruption symptoms, as well as the duration of the activity, began to be more like those existing before the earthquake. At present they are very much the same. However, the eruptions still recur almost twice as often. At first it was thought a satisfactory explanation for the increased eruptive behavior was found in that shortened duration of activity was compensated for by shorter intervals, resulting in a release of thermal energy comparable to the pre-quake condition. It is now known that there are additional factors. The duration of an eruption is now essentially the same as in pre-quake days, but the eruptions still occur with about 75% greater frequency. All of Great Fountain's symptoms following the earthquake were indicative of a mraked increase in thermal energy. Apparently some of this increase is persisting.

## What of the Future

Since discovery in 1869 Great Fountain has been one of Yellowstone's most important geysers. Like most big geysers it has shown great versatility. There is always the interesting enigma, what will it do next? There have been only brief periods when it did not erupt with a fair degree of regularity. It is difficult to ascertain just how long the present pattern of activity has characterized it. The period, so far as the total life of the mound is concerned, would seem to be brief, especially when it is considered that its surface deposits which have been growing since discovery, are but a thin veneer on the large pedestal which is the mound. Beneath the islands of beaded geyserite which have resulted from the present eruptive pattern, are thinly laminated sheets of sinter resting in a horizontal position. These sheets comprise over 95% of the mound. The eruptive activity in the historic period, and for a long time previously, is eroding into the older sinter. The erosion is in evidence all about the sides of the big pedestal and in the drainage channels. This clearly indicates that much the larger portion of the mound was deposited by a hot spring whose characteristics were different from the present Great Fountain. As is the case with most of the big geysers in the Firehole Basins, Great Fountain's mound is indicative of hotter water and more geyser activity in the last few hundred years than during an earlier period.

The higher eruptions in recent years, and other modifications, including an increase in thermal energy due to the earthquake, are indicative that Great Fountain might not yet have reached the zenith of its power or the fullest expression of the thermal energy which is inherent in its system. Barring unforseen incidents, such as an earthquake which might be destructive to its present underground structure, it is believed that a long period of major eruptive activity is still Great Fountain's potential. Some of this eruptive activity might well be more spectacular than has been witnessed to date.